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Night vision systems (NVSs) have revolutionized the combat operations of war fighters by denying the enemy the cover of darkness, and by providing greatly enhanced night flight capabilities. Navigation, safety, loadmaster coordination of air drop, target detection and target acquisition have all been dramatically improved due to the use and advances NVSs. Once limited to weapon aiming and surveillance, modern NVSs provide aircrew's with enhanced situation awareness of the night flight envelope, as well as a more effective way to complete military objectives. As NVSs become more common, and more capable, the role of the United States Air Force Flight Test Center (AFFTC) in testing those systems on aircraft continues to expand.

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NATO AGARD NIGHT VISION SYSTEMS TESTING DOCUMENT

United States Air Force Flight Test Center (AFFTC) Edwards Air Force Base Contribution to SCI-089/AG-300D

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NIGHT VISION SYSTEMS DEVELOPMENTAL FLIGHT TESTING AND EVALUATION

Background

Night vision systems (NVSs) have revolutionized the combat operations of war fighters by denying the enemy the cover of darkness, and by providing greatly enhanced night flight capabilities. Navigation, safety, loadmaster coordination of air drop, target detection and target acquisition have all been dramatically improved due to the use and advances in NVSs. Once limited to weapon aiming and surveillance, modern NVSs provide aircrew's with enhanced situation awareness of the night flight envelope, as well as a more effective way to complete military objectives. As NVSs become more common, and more capable, the role of the United States Air Force Flight Test Center (AFFTC) in testing those systems on aircraft continues to expand.

Introduction

One of the roles of the AFFTC is to test and evaluate NVSs in their developmental stages. Typically, NVSs are received from the manufacturer after laboratory testing has been completed; however, these systems are often not production representative. The role of the AFFTC is to test and evaluate these developmental systems so that

any problems are corrected before they enter the operational test stage where they must be fully production representative. A separate United States Air Force (USAF) organization called the Air Force Operational Test and Evaluation Center, or AFOTEC, becomes involved at that stage of product development. Generally, the tests completed at the AFFTC involve dynamic and integrated flight test conditions not possible in a laboratory. The role of the flight test center is to determine how successfully the NVSs will integrate with the aircraft in which they will be used. System and subsystem compatibility, utility, reliability, and effectiveness are common areas of concern, and these areas must be tested before the system is released to operational testing or subsequent operational use.

Often a NVS will be designed for use in multiple aircraft and the integration of that NVS with all the subsystems of a variety of aircraft becomes a further goal of flight test.

While not truly operational in character, the testing employed at the AFFTC attempts to mirror operational conditions in some critical areas, and one of those approaches is called envelope expansion testing. During this testing, the system under test may be subjected to extremes not even encountered in operational use. In other words, determining a system's operating limits must be done before any operational military use can occur. This type of testing is always done under highly controlled test conditions using trained test pilots.

The advantages to AFFTC developmental testing, are three fold: 1) structured test points allow variables of interest to be controlled; 2) experienced test pilots have been trained to evaluate even the slightest features of the system under test; and, 3) specially trained test engineers plan the tests and evaluate the resulting data. The combination of structured test and highly experienced test personnel allows a detailed evaluation to occur.

This developmental testing often detects and corrects design, or production-related issues before the item goes into production or is released to operational test or operational use.

OVERALL FLIGHT TESTING CONCEPT

While ground testing of NVSs occurs at the AFFTC, the primary focus is on dynamic, in-flight testing scenarios. In some cases, similar methodologies are used for ground test and flight test. For example, many AFFTC NVS tests obtain measures of visual acuity, and the same basic concepts which are used in a laboratory setting can often be used, with modification, in a flight test setting. Before any tests are performed, test pilots who have had NVS experience are selected for the evaluation team. Qualification currency with an existing NVS is also a prerequisite for flight tests. In some programs, pilots are sent to a Night Vision Goggle (NVG) refresher training course at the onset of a new NVS test program. Prior to the actual flight test, the test pilot's selected are checked on the test article's adjustment procedures and are then subject to a final check in an NVG compatible eye lane using standard NVG charts. Their visual acuity with the adjusted test NVS is then noted and used as their test baseline.

Another step prior to actual testing includes proficiency flights with the system under test, without collecting test point data. This step is important for safety-of-flight issues and pilot familiarity with the system under test. In many cases routine night flight operations are conducted as part of this process, often with twin seat aircraft with a pilot or copilot providing safety-of-flight redundancy.

After the previous system familiarization, and individual testing has been completed, flight test measures of visual acuity are initially taken on the ground using contrast boards viewed through the canopy or windscreen of an aircraft. Testing always begins with static objects like NVG visual resolution boards, or ground targets. After this initial testing is completed satisfactorily, and confidence is gained that the system will be safe in the flight environment, then visual assessments with dynamic movement are introduced. This testing often begins with perception of objects on the ground, and includes fixed targets or large image boards which can be used to determine overall visual detection or identification ranges. Common final test points are associated with more operational flight tasks where the pilot detects and identifies another aircraft under dynamic flight conditions. In-flight test points commonly use detection or identification range as the primary test metric. Other variables of interest always include measurement of ambient lighting conditions associated with the test flights. Moon phase charts begin the process of assessing the test lighting conditions but luminance levels associated with the actual test are double checked with low-light sensitive photometers.

TEST AND EVALUATION METHODS

The AFFTC uses a variety of methods to assess NVSs. It is also common for the test and evaluation of these systems to involve a combination of subjective and objective methods. Subjective methods are very commonly used, and typically involve techniques such as ratings, questionnaires, pilot interviews, pilot debriefings, and the generation of pilot and engineer concurrence on issues. Objective methods generally involve data that are more classically described by objective measures, and involves the measurement of areas like weight, force, inertia, etc.

The objectives in the following example test matrix were satisfied by test, demonstration, or analysis. In reference to AFFTC procedures, a test involves actual hardware placed in a physical test environment, where tightly controlled variables are manipulated. A demonstration may involve the use of the same items, but with a somewhat less structured set of test points, and an analysis may involve the interpretation of data using simulation, laboratory-type conditions, or data from a flight. All three types of evaluation may also be used concurrently. The test matrix which follows is accompanied by a discussion of the specifics of subjective and objective methods.

Table 1 Example Text Matrix for an NVS

Test Objective	Comments	Type of Assessment
Determine: System Compliance with Configuration Item Development Specifications (CIDS), Prime Item Development Specifications (PIDS) and Noncomplex Item Development Specifications (NIDS)	These objectives are specific NVS elements agreed upon by the using command and the System Program Offices (SPOs). Detailed requirements for each specific test program.	Test, Demonstration, and Analysis
Assess: Integration and compatibility with: hardware installation, cockpit compatibility, lighting, and aircrew maintenance systems	Generic NVS test areas	Analysis
Assess: Ejection compatibility: ejection seat compatibility, man-seat separation/disconnects, eye protection, ejection acceleration, windblast resistance, automatic separation, noninterference with parachute deployment, and descent procedures	Generic ejection compatible NVS test points	Test
Assess: Technical characteristics: weight and center of gravity (cg), structural integrity, and optical stability	Generic human biodynamic NVS test issues	Test, and Analysis
Assess: Human-system interface: fit, eye protection, comfort, integration with life support equipment and personal equipment, check-out and adjustment procedures, donning and doffing, ingress and egress, and maintainer interface, physiology including Valsalva procedure	Core Human Factors NVS integration areas	Demonstration and Analysis
Assess: Non-combat missions, special operations, ground ops support, goggle performance, diagnostics, and built-in test capability.	Determines special uses utility	Demonstration
Assess: Reliability and maintainability elements	Determines mechanical and system support, durability and maintainability over time	Analysis

Subjective Test Methods

All test methods used at the AFFTC ultimately lead to a final subsystem or system conclusion in three summary categories: Satisfactory, Marginal, or Unsatisfactory. These categories reflect all test elements, and provide a final judgment involving all elements and requirements being tested.

Many specific subjective approaches have been used at the AFFTC to contribute to these three final conclusion possibilities. Typically, the beginning stages of the AFFTC test approach reflect on the ability to perform the mission in terms of specific requirements set by the user command. These requirements are usually translated by the SPO and the AFFTC into test points, which are, in turn, assessed by subjective and objective measures. Occasionally, the contractor of the system under test is involved with both test planning and test conduct, usually under an integrated product team (IPT) concept with the AFFTC and SPO.

Some test programs have used open-ended subjective inquiry, some have used yes or no questions and some have used rating scale approaches. Overall, the rating scale approach is the most popular, followed by yes/no types of questions and then finally by an open-ended subjective inquiry. Each approach has advantages and disadvantages, and is tailored to specific systems evaluations. For example, an open-ended questionnaire may be used on an entirely new system when the capabilities of the test article are not well defined, or when the system has never been flown in a particular aircraft. The first NVSs programs at the AFFTC used such an approach when NVSs were new technology in aircraft. Later programs became more comparative with comparisons being made between earlier NVSs and later NVSs or system enhancements. A primary benefit to subjective testing is that the pilot's previous experience serves as a benchmark to measure against.

Numeric values created by various subjective rating systems assess positive and negative elements of the systems under test and then may be aggregated into conclusions by subsystem and then by the system overall. This process can include considerable reliance on specialized descriptive and inferential statistics which translate numerous subjective rating values into summary conclusions. Being a subjective process overall there is also a reliance on engineering and aircrew judgment to qualify the impact of numeric ratings, and to further refine the overall importance of the results obtained.

The AFFTC's Human System Integration Branch in particular, has expended considerable effort to ensure that subjective rating systems are industry accepted, systematic, psychometrically sound, linguistically balanced, and not subject to excessive response bias. Historic, subjective rating systems such as the Cooper-Harper, Bedford, United States Air Force School of Aerospace Medicine (USAFSAM) and AFFTC six-point rating scale are often supplemented by more specialized subjective tools such as the Subjective Workload Assessment Technique (SWAT). It is worthy to note that there is no one method used overall at the AFFTC to assess NVS subjective data. Subjective methods are chosen by team efforts on the part of the AFFTC, the SPOs, the item contractor, and the customer. The only overall AFFTC direction provided for systems under test is that the final judgment reaches only one of the following conclusions: satisfactory, marginal or unsatisfactory.

Objective Test Methods

The use of objective methods for NVSs often relies on dedicated test points accomplished on the ground, or during in-flight tests. Objective data also involves measurement of visual processes associated with NVS.

Because NVSs are currently a human-mounted system, the objective data accruing from tests are often intermingled with subjective judgments. As another example, biodynamic measures of helmet lift loads, or center of gravity for an NVG system can result in calculations of head and neck loads which are imparted to an aircrew during dynamic flight. While these measures can be calculated using an objective engineering approach, their impact on aircrew can still result in a high variability of subjective response. A certain neck load for a small pilot (5th percent in body weight) may be excessive and result in unacceptable strain, whereas during the same flight conditions, using the same equipment, the test may result in no discomfort for a larger pilot (95th percent body weight). In some cases there may be an objective criterion such as a maximum neck load (representing a worst case situation) that would result in a pass/fail assessment, thereby precluding a subjective judgment of discomfort. In this case, and in many cases of human-machine interaction, the objective data imparted by a loads analysis must be tempered with both the subject's physical characteristics as well as the subjective effect that system loading has on the human's performance and well being.

One of the objective measures collected for such tests includes measures of anthropometry on the test subjects selected. Anthropometrics involves the measurement of human body dimensions, with the goal of comparing individuals to a larger population. Using this objective tool, inferences can be made about the suitability of an NVS for the larger population of USAF aircrew. Using the test subject as their own control, subjective response data can also be coupled with objective comparisons of that same subject.

Other types of objective data tested are derived from NVS program specifications, and include areas such as windblast resistance, weight, and center-of-gravity issues. Examples of these tests would include observation and analysis of the physical properties of the NVS under specific test conditions, for example, system response to a 400-knot windblast. Other tests would include observation and analysis of goggle trajectories during sled test ejections of mannequins wearing ejection compatible goggles. These types of tests usually involve visual analysis of high-speed video, and subsequent visual inspection of the test article.

Examples of AFFTC NVS Test Methods for Various Programs

YA-10B Aircraft and AN/AVS-6 Night Vision Goggles

One of the earliest NVS tests to occur at the AFFTC was the testing of the AN/AVS-6 NVG. Accomplished from October 1982 through January 1983, this test program used the YA-10B aircraft as a flying test bed, with additional ground tests performed on the F-15B, F-16A, F-111D and A-7D. Objectives for the test involved assessing the usability of those goggles for night attack roles, formation flying, low level navigation, air-to-ground gunnery, as well as integration with limited and full avionics suites.

Additional objectives included determining minimum ambient light levels for navigation using the NVGs as sole sensor, determining avionics display interactions, such as the use of forward looking infrared radar (FLIR), the employment of illumination flares, the effects of cockpit lighting modifications and the overall impact on pilot workload. The in-flight tests were primarily conducted at low level (200 to 300 feet Above Ground Level [AGL]) over open terrain, and at 500 feet AGL in mountainous terrain.

Specific methods used in this test included assessments of in-flight conspicuity of chase or lead aircraft, and the ability to take-off and land with runway lights blacked out. Lighting conditions were manipulated from clear starlight to half moon or greater illumination. Interactions with head-up display (HUD) and FLIR imagery were assessed as well as visual perception issues such as determination of distance to clouds, and discrimination of terrain features such as hills, mountains, deserts and bodies of water. Pilot workload was assessed using the SWAT subjective workload rating system. A list of open-ended questions were asked of the pilots to assess visual issues such as field-of-view, field-of-regard, and depth perception for 10 separate flight operations. Additional questions covered avionics compatibility with HUD and raster video, canopy lighting, reflections, dark adaptation time, goggle adjustment, gun flash effects on vision, maneuverability, detection ranges, g-effects, and effects on instrument crosscheck. In addition, several general questions were asked relating to the necessity and utility of the NVGs for their intended mission, as well as questions discussing strong points and weaknesses of the goggles. Since this was the first major in-flight test conducted at the AFFTC, many open-ended questions were asked in order to determine an overall understanding of how the AN/AVS-6 would interact with a fighter aircraft under numerous test conditions.

MC-130H Combat Talon II Aircraft

From 1987 to 1989, a test program was conducted on the MC-130H Combat Talon aircraft. The purpose of that test was to assess the compatibility of the aircraft lighting with NVG systems

F-15 and F-16 Testing of Cats Eyes and Nite Ops Goggles

In 1991 a small series of tests were completed on the F-15 and F-16 aircraft of the developmental Cats Eyes and Nite Ops NVG systems. A seven-point rating scale of acceptability was used for the ground evaluations. Areas assessed subjectively included: donning and doffing, interpupillary goggle adjustment, eyepiece focus, vertical adjustment, fore and aft as well as tilt adjustment, eye relief, peripheral vision and display and cockpit lighting. Testing included a variety of static cockpit compatibility tests, followed by limited flight testing. A separate F-15 night tactics test questionnaire was also used for conventional USAF NVGs (F4949) in the same time frame.

C-17A Aircraft

From July 1992 to March 1995 an assessment was made of the C-17A's compatibility with the projected image, Type II, Class B, GEC Mark IV Cats Eyes, as well as the

International Telephone and Telegraph (ITT) F4949 Type I, (with Class A and Class B filters) NVG. Three areas of interest for this test were: ground testing, flight testing above 10,000 feet AGL, and operationally representative low-level flight missions (at or above 900 feet AGL). A six-point, bipolar, subjective scale of adequacy was used.

Areas of interest included primary flight displays and controls, external visibility, windshield light transmittance, and external night visual acuity. Flight segments included: preflight, cruise at 12,500 feet, a 3-degree approach, a go-around, a 5-degree approach, and an airdrop. Moon conditions were 48 percent illumination for the in-flight tests. Ground tests used a projected image bar chart display. Luminance was controlled for ground tests by placing the aircraft in the USAF Benefield Anechoic Facility (BAF) where lighting levels could be precisely controlled. For certain tests where exact specification lighting levels were specified, but could not be met exactly, the differences in lighting from those conditions were compensated for by use of a scaling factor method.

F-16 NVG Testing

Numerous NVSs have been tested on the F-16 aircraft. Testing on Block 25/30 and 32 aircraft in 1996 covered the following: egress, maintainability, transportability, glare, reflections, light leaks, cockpit lighting, and perception of labels/legends/displays. Assessments were made of minimum resolvable angles through line grading charts or the use of a Bailey-Lovie visual acuity chart. Ground testing also involved the external perception of the aircraft at 0, 45, 90, 135 and 180 degrees aspect angle, with aircraft detection, identification and aspect angle being test criteria. Flight tests involved subjective ratings using a six-point rating scale and were made for formation, low-level navigation, air-to-ground, air-to-air attack, and instrument flight. Later testing of the F-16 C/D involved special operations flight profiles.

AN/AVS-8 (V) Night Vision System

This NVS was flight tested between 1996 and 1997 and consisted of three versions. Versions 1 and 2 were ejection compatible goggles containing new eye protection visors, and an integrated chin and nape strap for the base helmet. Version 3 was a helicopter version with a sand and dust visor. Testing of this new goggle system was extensive and involved lighting, windblast, ejection tower, goggle-helmet separation, man-seat separation, centrifuge testing, weight and cg testing, hanging harness, sled tests, and reliability and maintainability issues. Laboratory testing was completed in association with flight testing and the AFFTC was the responsible test organization (RTO). Additional laboratory testing was conducted at a variety of specialized NVS testing laboratories.

This NVS was tested by the AFFTC in an F-16, C-141 and C-17 from overcast starlight levels to as much as .89 moon illumination. This test program used standard F4949G NVGs as control goggles for the test.

Windblast testing involved speeds from 350 to 600 knots in A-10 and B-1B simulated cockpits. During live windblast tests an instrumented Hybrid III 95th percentile male mannequin was used. The mannequin was outfitted with combinations of standard life support gear including: HGU-55/P helmet, MBU-12/P and MBU-20/P masks, the LPU-9

support gear including: HGU-55/P helmet, MBU-12/P and MBU-20/P masks, the LPU-9 life preserver and SRU-21/P, SRU-12/P, and CSU-17/P survival vests, the PCU-15/P torso harness with CRU-60 or CRU-94 connectors, the CWU-27/P flight suit, and the CSU-13B/P anti-g suit. The mannequin was instrumented with a Denton load cell to measure neck lift loads and moments. Numerous tests were accomplished using several configurations of the ACES II ejection seat system.

Ejection tower tests were accomplished using A-10, B-1B, and F-16 configured seat systems. These tests assessed general ejection compatibility prior to more extreme rocket sled tests. Ejection tower tests used 5th and 95th percentile Aerospace Hybrid II mannequins.

Centrifuge testing included assessments of helmet and goggle movement with a live test subject. Instrumentation determined the degree of movement of the NVS as well as the pilot's helmet.

Sled tests used an F-16C, F-16D and A-10A fore-body with an ACES II configured seat. Like the ejection tower tests, the sled tests used Hybrid III male mannequins. Sled test speeds varied from approximately 250 to over 600 knots. Sled testing is significantly more dynamic than tower testing since the dual elements of full ejection loading is coupled with high-speed windblast as the mannequin ejects, and is recovered by the a parachute process. Flight testing occurred on Air Mobility Command (AMC) aircraft using operational aircrew, rather than AFFTC test pilots. It included testing of the second version NVS on C-5, C-130, C-141, KC-135, and C-17 aircraft. A simple six-point, bipolar 1 to 6 numeric value rating scale using descriptive adjectives measuring levels of satisfaction was used. This test also used a 1 to 5 numeric and descriptive adjective rating scale to compare the NVS second version to both the earlier production ANVIS-6 as well as production F4949 NVGs.

The subjective measures of effectiveness used on the flight portion of the test included assessments of whether the NVS version 2 was meeting or exceeding the capability of the current NVGs (F4949 NVGs) then in use by that USAF command. Test areas included: meeting mission tasks, meeting mechanical and physical requirements of flight, ability to see inside the cockpit, to acquire external targets, meet all aviation requirements, training requirements, maintenance instructions and documentation, mobility and transportation requirements, egress/escape requirements, and to assess its reliability to support mission requirements.

Specific Human Factors form-fit-function questionnaires were also used in this test, in an F-16 aircraft on the ground and pilot ratings on a 1 to 6 numeric rating scale of satisfaction were used. This bipolar scale had no neutral point and had three categories of satisfactory and three levels of unsatisfactory for the scale. This subjective measure rated: goggle-to-aircraft connection and disconnection capability, one hand and two hand goggle manipulation, donning and doffing procedures, eye protection with and without spectacles, ability to perform the Valsalva procedure, head mobility, comfort, helmet balance, as well as including an overall numeric rating for the system.

Finally, the system was tested for maintainability and reliability factors which included: module replacement, time to repair, adjustment capability, independence of failures, maintainer skill levels required to repair, organizational level repair, preventative maintenance ease, and fault isolation.

C-130J Aircraft

This evaluation was conducted from April 1998 through June 1999 and involved both ground and in-flight testing of F4949L (Class B) and F4949D (Class A) NVGs in the C-130J. Areas of interest were cockpit compatibility as well as the cargo area. In the cargo compartment, overhead lighting, floor lighting, jump lighting, and aft side door lighting were assessed. Instrumentation lighting was tested at specified luminance levels of approximately .1 foot-Lambert (fL) for primary and secondary displays, and multicolor and monochrome displays were specified at .5 fL ambient. The windscreen and HUD combiner were also areas of interest.

C-141C Aircraft

Night vision systems tested in the C-141C in 1999 included F4949D and F4949G goggles with emphasis placed on cockpit display NVS compatibility, as well as external visibility visual acuity tests. Ground testing of external visibility at night involved the use of the Medium Contrast Resolution Resolving Power Target (USAF Tri-Bar chart). Visual acuity was based on the conversion of the USAF tri-bar charts to Snellen visual acuity values. Visual acuity values were analyzed and then extrapolated to determine visual acuity potential in flight.

F-22 and F/A-22 Aircraft

The AFFTC assessed the F-22 aircraft using conventional F4949 NVGs by laboratory and simulator analysis from 1997 to 2000, and on the F/A-22 from 2000 to the date of this report. Cockpit compatibility tests were performed to ensure that the F4949 could be used in the F-22, and that its cockpit and external lighting was NVG compatible lighting. Test areas of interest included: pilot life support equipment physical compatibility, overall cockpit fit compatibility, specific cockpit night lighting capability, external aircraft lighting NVG compatibility, and external pilot vision capability. Ground tests were performed in special hangars with natural moon light levels providing approximately 50 percent moon luminance equivalent. Psychometric visual perception charts were developed to measure test light levels. Those charts were based on spectral color perception and object visual resolution capabilities of a USAF pilot population. These charts used colors and objects of known sizes to correlate known resolution and visual perception of the USAF population to the specifics of a particular test group, in effect, establishing what the low light levels were without relying on a photometer.

Objectives for the F/A-22 for NVS included fully compatible internal and external lighting, pilot external visual acuity with NVGs, and life support equipment compatibility with F4949 NVGs. Objective data collected included measurement of light emissions for NVG compatible lighting, and interaction with displays of the aircraft. Pilot subjective comments on the suitability of the NVGs with the aircraft were also collected and analyzed. Other areas of interest were assessments of reflection ejection suitability, windblast, stowage, donning and doffing, and pilot ingress/egress. The AFFTC is continuing to assess NVS compatibility with the F/A-22 aircraft.

Integrated Panoramic Night Vision Goggles (IPNVGs)

This test program was conducted between March and April of 2003 and involved the testing and comparison of the Integrated Panoramic Night Vision Goggle (IPNVG) with USAF issue AN/AVS-9 (F4949) NVGs. The test aircraft was an F-16B, and the test was conducted through the USAF Test Pilot School. The IPNVG provides a wider field-of- view than issue NVGs, and is worn on a conventional flight helmet the same as USAF issue NVGs.

Objectives included comparing situation awareness, workload, and effectiveness of IPNVGs to F4949 NVGs. Luminance levels for the test were in two categories: 0 to 25 percent moon illumination and 75 to100 percent moon illumination.

This test used pilot physical performance time for a matched task, within-subjects assessment of the effect each NVG had on pilot situation awareness. This was a direct assessment of situation awareness as measured by an individual's performance times on several tasks where two different NVGs were worn. The same flight profiles involving unusual attitude recovery, radar cursor movement reaction time, and target visual capture time were also used for assessing workload using the two types of NVGs. Pilot attention to a radar cursor position change while performing a station keeping flight profile assessed the pilot's level of situation awareness. In another test case, the time required to acquire and capture a target on the HUD was used to assess situation awareness of the target as being affected by NVG type.

The workload assessment was based on comments, and subjective ratings provided through the AFFTC seven-point workload estimate scale. This workload scale rates workload on a range from 1 (nothing to do) to 7 (overloaded, system unmanageable). Its ordinal-level resultant values were compared and analyzed using non-parametric statistical tests.

The suitability of the IPNVGs assessed using several flight profiles also included assessments of field-of-view when maneuvering under high g-loads, and an assessment of the military utility of the IPNVG system.

CV-22 Tilt-rotor Air Vehicle

The new tilt-rotor CV-22 air vehicle will be assessing the use of conventional NVSs in several areas: cockpit compatibility, gauge visibility, display compatibility, HUD compatibility, and functionality of HUD with NVS. These test points involve a variety of flight conditions, as well as use by left or right seat aviators. Assessment ratings will use the AFFTC six-point rating scale for absolute ratings of operator satisfaction. Flight testing is beginning on this new air vehicle (2003) with NVS integration testing currently being scheduled in test plans.

TEST METHODOLOGY DISCUSSION

Test Item Evaluation Criterion

The establishment of test item criterion is usually governed by a concurrence of the AFFTC testers, a SPO, and the using Command. Program objectives are often written of requirement thresholds and objectives, and from those, the system objectives are often used as a base criterion for flight testing. In the case of objective data, pass/fail criterion are relatively easy to set. For example, if an item is designed to survive a 600-knot windblast test and remain fully functional, the subsequent inspection of that item post-windblast can pass or fail that requirement based on a single test. However, single-event tests are not always the accepted test approach, and the ability to pass a system often hinges on several trials under differing test conditions. Providing multiple test events for any particular requirement builds confidence in the ability of that product to successfully complete its role in an operational setting, as well as building a reliability history, which also instills confidence in the test approach and sustained durability of that product.

Build-up and Additional Testing

Requirements are often tested using a build-up approach, where progressively more severe limits are reached and then exceeded. The build-up approach provides a safe approach to determining product limits, while providing good data on all the ranges of the systems operational envelope.

Variation in the pass/fail approach for objective requirements varies by program, with smaller programs typically limiting test redundancy for budget or other concerns, while larger programs, or more complex weapon systems, warrant more repetition during test. In all cases, time and schedule drive the ability to collect data, and thus provide constraints under which pass/fail conclusions can be drawn. However; whenever possible, more testing results in greater confidence in the final conclusions.

SUMMARY

Night vision systems have been and are being tested on a regular basis at the United States AFFTC. Performing developmental test on NVSs allows them to either be immediately fielded, or moved on to operational testing by an independent operational testing agency (OTA). For the USAF that OTA is AFOTEC.

Central to the AFFTC testing concept for NVS is the idea that the AFFTC can often provide the first integrated developmental tests, in a variety of airframes and under tightly controlled conditions. Our ability to provide dynamic flight environments with highly trained test pilots and correspondingly trained flight test engineers provides a typical first-look at the possible operational utility of new or modified system.

Methods used at the AFFTC include both objective and subjective data collection and analysis. Testing often follows a build-up approach and then an envelope expansion stage where the items are tested under dynamic conditions to their design limits or beyond. Regression testing provides redundant test efforts in order to build confidence in the

projected utility the item will have during its operational life. Analysis of all data collected during the evaluation is complex, but it is particularly complex when dealing with subjectively derived performance requirements or specifications. However, specially trained engineers, test pilots, and integrated product teams can provide such analysis and insight to ensure that the developmental product received for test can be confidently released for field use or further operational testing.

Acronyms

AFB - Air Force Base
AFFTC - Air Force Flight Test Center
AFOTEC - Air Force Operational Test and Evaluation Center
AGL - above ground level
AMC - Air Mobility Command
BAF - Benefield Anechoic Facility
CA - California
cg - center of gravity
CIDS - Configuration Item Development Specifications
fL - foot-Lambert
IPNVG - Integrated Panoramic Night Vision Goggle
IPT - integrated product team
ITT - International Telephone and Telegraph
NIDS - Noncomplex Item Development Specifications
NVG - Night vision goggles
NVS - Night vision systems
PIDS - Prime Item Development Specifications
RTO - responsible test organization
SPO System Program Office
SWAT - Subjective Workload Assessment Technique
USAF - United States Air Force
USAFSAM - Untied States Air Force School of Aerospace Medicine